

# Case Study 120

## Energy efficiency in refurbishment of industrial buildings

### John Brown Engineering Ltd Clydebank Dunbartonshire

- Reduction of 40% in buildings-related energy consumption and 34% in CO<sub>2</sub> emissions
- Contract Energy Management – no capital cost to company
- Building Energy Management System
- Replacement radiant space heating system
- Lighting upgrade
- Installation of fast-acting door
- Improved roof insulation

#### Background

John Brown Engineering Ltd (part of Trafalgar House plc) is an international contracting and project management company in power engineering, sewage and water treatment. This Case Study concerns part of the company's Clydebank site where it used to build ships, but now manufactures heavy duty industrial gas turbines.

The site comprises principally two large manufacturing/assembly areas known as the engine works and the fabrication works. In construction these consist of long, partly glass-roofed workspaces ranging in height from 11 to 24 m. The remainder of the site is taken up by smaller manufacturing units and office accommodation. The total site staff is about 1500.

#### Summary

This Case Study covers the engine works, associated offices, and joiners shop. A major refurbishment of this area took place in 1989 and 1990, covering some 24 600 m<sup>2</sup>



View of site

of production area and 5200 m<sup>2</sup> of office accommodation.

An Energy Efficiency Office grant-aided energy survey in 1987 recommended the following.

- Replacement of the inefficient steam warm air heating system with a gas-fired radiant system.
- Installation of a Building Energy Management System (BEMS).
- Replacement of the old inefficient boiler serving the general offices.

Using the survey results and taking account of the limited capital available, the company entered into a seven-year Contract Energy Management (CEM) agreement.

As a result of the refurbishment carried out under CEM, the control of space heating has improved dramatically and annual gas

consumption for this area has been reduced by 38% from 21.56 million kWh in 1988/89 to 13.37 million kWh in 1990/91, a saving that is worth about £81 900 per year (see 'energy costs' box). In addition, significant maintenance and manpower savings of about £48 000 per year have resulted from the replacement of the old steam systems. (1992 prices are used in this document, unless otherwise stated.)

#### Management Policy

Prior to commissioning the EEO grant-aided energy survey in 1987, smaller more specific studies had been carried out by independent consultants.

These studies gave the company's management an insight into the potential for energy savings within its buildings. The full extent of these potential savings and the mechanism for realising them was confirmed with the issue of the energy survey report.



Energy Efficiency Office  
DEPARTMENT OF THE ENVIRONMENT

“A Contract Energy Management arrangement has been a successful route to a reduction in energy consumption”



## JOHN BROWN ENGINEERING LTD

A vigorous approach was then adopted for implementing these recommendations, which included negotiations with various Contract Energy Management companies.

John Brown Engineering did not have an energy manager, and the senior managers were jointly responsible for ensuring that all the options open to the company were fully explored.

The CEM contract with Inenco Energy Ltd is based upon shared savings during the seven-year duration of the contract. Inenco therefore has a considerable vested interest in reducing the energy consumption of the premises.

Regular monitoring of energy by the facilities manager has become routine management practice and will remain so when the CEM contract has run its course.

### Building Services Before Refurbishment

Prior to decentralisation of the space heating in 1989, all areas were heated directly or indirectly by steam.

The primary source of steam during the winter months was from two packaged boilers fuelled by interruptible natural gas, with Class D light fuel oil as specified in BS 2869: Part 2: 1988. These boilers supplied steam to the following.

- Warm air fan-assisted unit heaters in the engine works, with temperature control by column mounted thermostats. (These thermostats were in poor condition, and those that still functioned were usually set to maximum by unauthorised personnel.)
- Radiators in the Wallace Street offices which had no facility for automatic temperature control.
- Heater batteries in six air handling units (AHUs) serving the general offices. (Control was by a duct sensor in the air stream from the AHUs).
- Calorifiers for hot water in both office areas.

Space heating was provided in the two main office areas for a slightly longer period than the engine works. The spring and autumn space heating requirement and summer hot water needs for the general offices and the Wallace Street offices were provided by separate steam boilers.

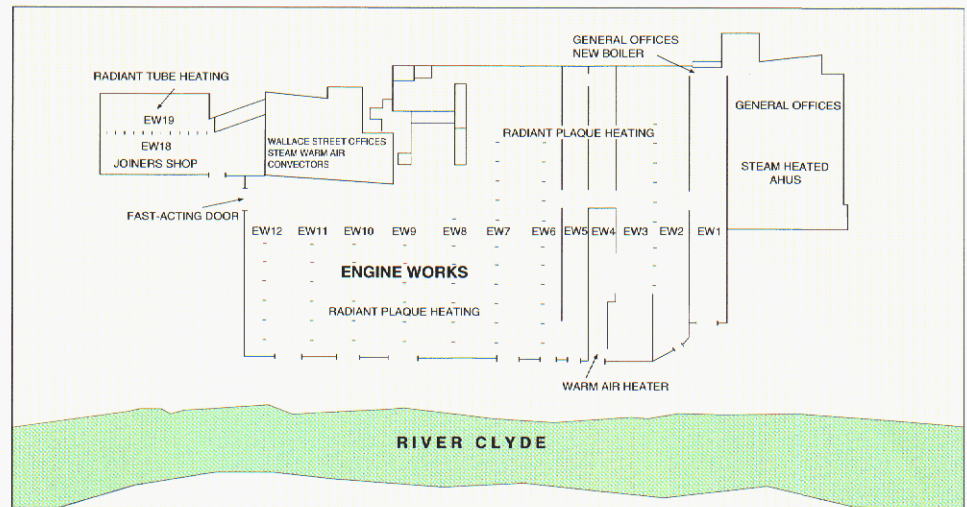
### Refurbishment 1977-1981: Re-roofing

Approximately 8350 m<sup>2</sup> of factory bays in the engine works were re-roofed with polystyrene insulated profiled cladding and double skin rooflights, primarily to improve building integrity. The U-value of the roofing is 0.6 W/m<sup>2</sup>K, an improvement of some 90% on the original 100% glass roofs.

The cost of this work would be approximately £370 000, the additional cost over an uninsulated roof being about £92 500. This would achieve annual savings of £22 500.

### Lighting

The mercury light fittings in the engine works were replaced by higher efficiency sodium lamps between 1978-80, reducing the electrical load from 304 kW to 143 kW and improving the lighting levels from 200 lux to over 300 lux. The cost of upgrading which included major



Site plan

re-wiring, was nearly £89 000. Savings depend directly on the hours of use. Using a utilisation factor of 50% gives annual savings of £16 250. The system power density is about 1.7 W/m<sup>2</sup> per 100 lux, and lighting consumption at 22 kWh/m<sup>2</sup> is good for a building of this type, which is attributable to efficient lighting and good manual housekeeping.

### Refurbishment 1989-ongoing: Contract Energy Management

The seven year CEM contract entered into, covered the following measures:

- replacement of space heating system
- installation of BEMS
- installation of fast-acting door
- replacement of general offices boiler.

The contract is based on predicted energy savings of just under 35%, and guarantees John Brown Engineering a minimum level of cost saving each year, without capital expenditure.

Actual savings in running costs are computed annually. Any savings in excess of predictions are shared between John Brown Engineering and Inenco in undisclosed proportions.

The total invested by the CEM company in 1989 was £350 000. At the end of the seven-year CEM contract the installed plant becomes the property of John Brown Engineering, and the company will benefit from the full energy savings achieved.

### Replacement of Space Heating

In August 1989, a radiant heating system was commissioned and the two main boilers serving the engine works were taken out of service.

A total of 218 plaques and 18 tubes were installed giving a total capacity of 5462 kW. Radiant plaques were calculated to be more economical than tubes in the long term. However, tubes were required in the joiners shop as plaques were a fire risk in the woodworking areas. A ducted gas-fired warm air heater was installed in the No 4 stores bay.

In addition, the general offices' boiler, which was 20-years old and only 63% efficient, was replaced by a new packaged steam boiler

(efficiency 82%). The Wallace Street offices steam boiler and radiators continue in use.

### Building Energy Management System

The space heating for the engine works and joiners shop was arranged into 52 zones to enable the computerised Building Energy Management System to provide heating in direct relation to work shift times (allowing reprogramming for overtime). The BEMS installed is the CEM company's own 'in-house' system. The temperature in each zone is controlled via 'black bulb' temperature sensors.

The BEMS automatically logs the time and temperature of the optimum start, minimum and maximum temperature, and hours of heating. Following installation, it showed both Inenco Energy and John Brown Engineering that two zones were not being adequately heated, enabling appropriate action to be taken to rectify this.

Plans are in hand to incorporate the time control of the factory bays' lighting circuits into the BEMS, and trials are underway.

Temperature sensors were installed to the office areas for monitoring purposes. There is no BEMS control of the individual ducted warm air system for the general offices. It was considered at the time that because of the relatively poor condition of these air handling units the cost to replace all the valves and associated equipment was too high, and control of this area by the BEMS was deferred until a later date. The boilers serving both the general offices and Wallace Street offices are under the control of the BEMS.

### Fast-acting Door

A fast-acting door, 2.4 m x 3.7 m, between bay 12 and the outside, was installed in 1989. This door allows fork lift truck movement from the open courtyard used for storage. It is operated by push button for pedestrians and induction loop for vehicles and takes 3 seconds to open or close. The door replaced the heavy rubber double door which had become badly twisted by repeated blows from fork lift trucks. This gave rise to excessive air ingress and discomfort from cold draughts.

The savings from this measure have been calculated at 486 000 kWh per annum.



### Refurbishment Work Outside the CEM Contract

The roof of Bay 10 was replaced in June 1990 (1378 m<sup>2</sup>). The new roof was made up of a composite panel of plastic-coated steel sheets with a 35 mm polyurethane insulation filling giving a U-value of 0.4 W/m<sup>2</sup>K. This work was carried out to improve the integrity of the building as the existing roof was not watertight. This was funded outside of the CEM contract as it had been agreed at the outset that re-roofing would be excluded.

At 1992 prices, this work would cost £65 400. Since the roof had to be replaced, the cost of incorporating energy efficiency is the additional cost over an uninsulated roof. This is about £16 350, and would achieve annual savings of £3600.

### Energy Use and Costs

The annual energy consumptions and costs for the year ending September 1991 (not normalised) were:

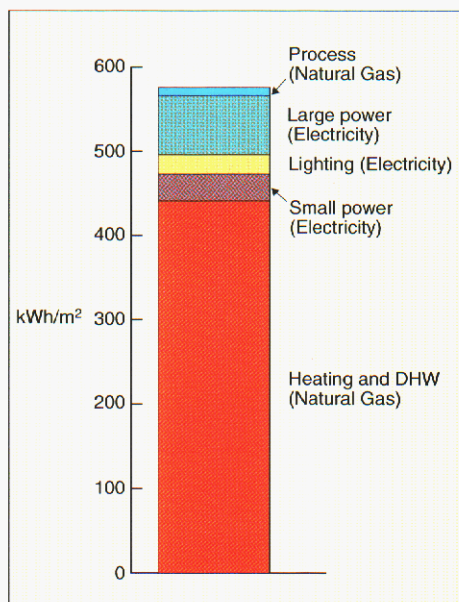
Gas:	13.37 × 10 <sup>6</sup> kWh	£133 700
Electricity:	3.78 × 10 <sup>6</sup> kWh	£189 000

This includes about 0.3 × 10<sup>6</sup> kWh of gas and 1.97 × 10<sup>6</sup> kWh of electricity used for process. Process gas is consumed in the treatment of finished steel components, ie in the caustic tank, heat treatment furnace and salt baths. The large electrical process requirement is for the turning, boring and shaping of the turbine castings. The load-pack gearbox test bed is now all electrical since decentralisation. Energy consumption by end use is shown in the bar chart below.

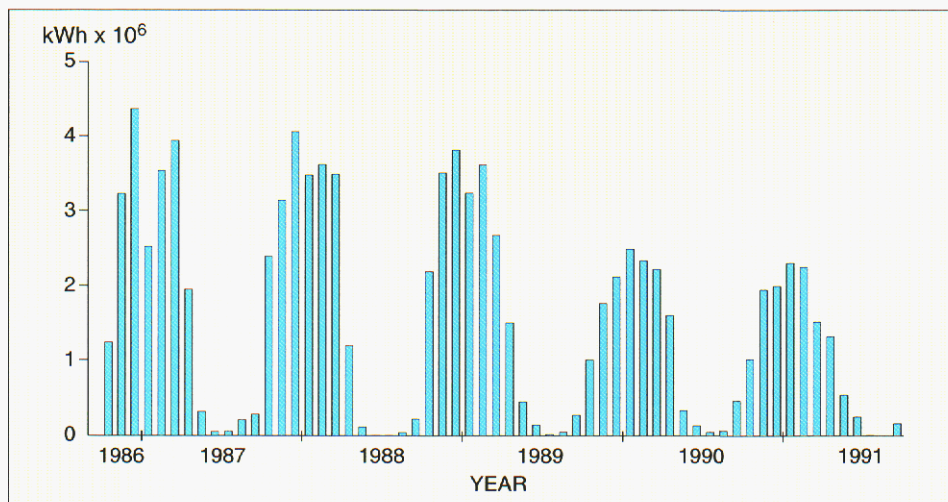
The bar chart above presents the gas consumption for the engine works, joiners shop and associated office on a monthly basis from October 1986 to September 1991. This chart clearly portrays the significant reduction in gas usage as a result of the refurbishment measures employed.

### Energy Performance

Energy consumption values for John Brown Engineering are given here for comparison with the values from Energy Consumption Guide 18<sup>[1]</sup>.



Graph 1 Energy by end use 1990/91



Graph 2 Monthly gas consumption

taking into account the effect of building height, occupancy and other influences.

John Brown Engineering building-related annual energy consumption values (in kWh/m<sup>2</sup>):

	1988/89	1990/91
Fossil fuel	742	422
Electricity	57	57

(The space heating component in these values has been corrected for weather using degree-days, a correction of +4% in 1988/89 and -3.9% in 1990/91.)

Energy Consumption Guide 18<sup>[1]</sup> indicative annual values for a 'General Manufacturing' type building, typically 8 m in height with two shift operation (in kWh/m<sup>2</sup>):

	'Typical'	'Improved'
Heating and hot water (fossil)	325	225
Electricity	85	65

John Brown Engineering's occupancy is two shift. The building height however is about 13 m, which will increase the heating energy consumption significantly. Allowing for this, fossil fuel consumption compares reasonably well.

Electricity consumption also compares well. (Energy Consumption Guide 18<sup>[1]</sup> and Introduction to Energy Efficiency in Factories and Warehouses<sup>[2]</sup> give further information.)

John Brown Engineering has achieved an overall 40% reduction in buildings-related energy consumption between 1988/89 and 1990/91. This has resulted in a 34% reduction in carbon dioxide emissions. The energy cost saving is less, owing to the change from interruptible to firm gas required for the new heating system. The actual saving is sensitive to the price difference, but using the typical values in the 'energy costs' box (overleaf) gives a cost saving of 20%. Significant maintenance and manpower savings valued at about £48 000 per year have also been achieved from replacement of the old steam boilers.

The monthly degree-day graph (graph 4, overleaf) shows best fit lines through monthly energy consumption data against monthly degree-days. The reduced slope of the 1990/91 line indicates a reduction in energy consumption, and the improved correlation coefficient indicates improved control, with heating energy consumption responding appropriately to changes in external temperature.



View of engine works, showing radiant plaque heaters and sodium lamps



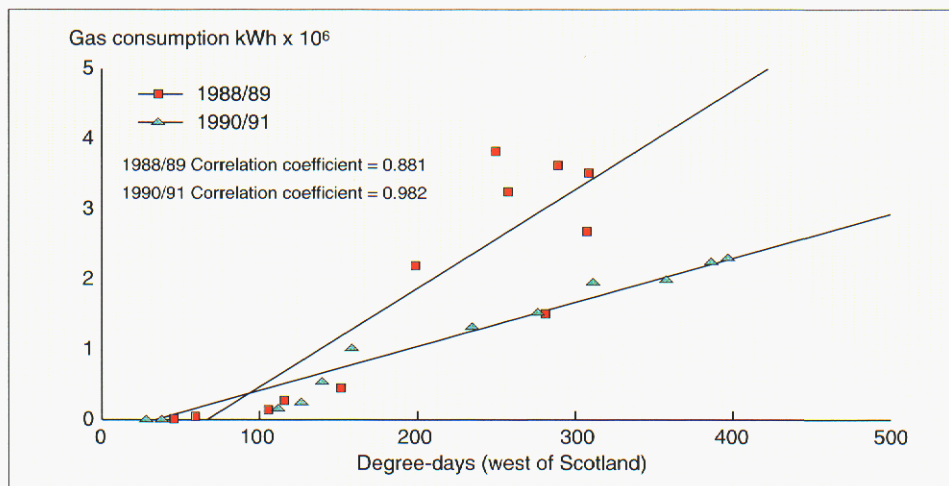
### User Reaction and Appraisal

One of the major problems after the installation of the new heating system was convincing the workforce in the engine works that a heating system not directly heating the surrounding air could maintain a satisfactory working environment. The original warm air system was inefficient, badly controlled, and in need of overhaul, but gave a working environment that the original energy survey report described as comparable with an office. However, problem areas existed, especially adjacent to large access doors, where heating was affected by draughts.

It was not surprising that the introduction of a new heating system, with remote temperature controls that could only be adjusted by staff operating the BEMS, initially caused some comment. Following this initial period, the workforce has come to appreciate the benefits of an efficient and reliable space heating system. In addition, the benefits of the fast-acting door are appreciated by those working in the adjacent bays.

### Conclusions

The experience of this site illustrates the significant reductions in energy costs which are achievable in the apparently unpromising circumstances of an ageing structure. The use of CEM for measures implemented from 1989 onwards provided project finance without



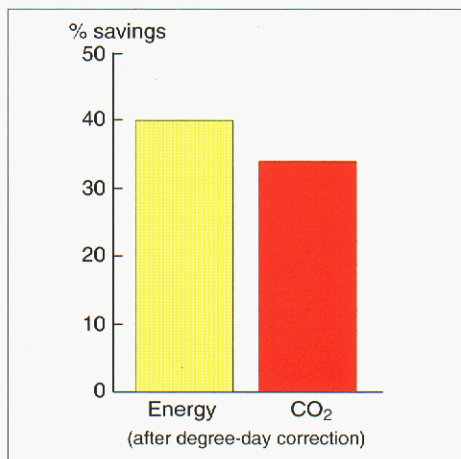
Graph 4 Monthly degree-day graph

outlay of capital by John Brown Engineering. Expenditure of over £350 000 was therefore saved for other purposes, while successfully achieving a reduction in energy consumption. The commitment, achievements and energy performance of John Brown Engineering have enabled them to become accredited by the Energy Efficiency Accreditation Scheme (developed by ESTA and the Institute of Energy, with the support of the EEO).

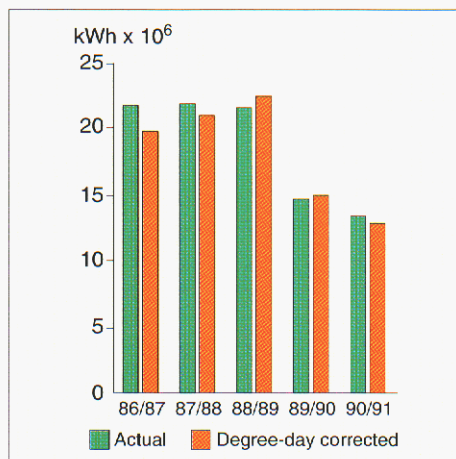
### Environmental impact

Burning fuel to generate energy produces gases from extraction, processing, delivery and combustion of the fuel, at power stations or on site. Carbon dioxide (CO<sub>2</sub>) especially is a major contributor to the greenhouse effect and the threat of global warming. The government is committed to reducing CO<sub>2</sub> emissions. Efficient use of energy not only reduces costs, but also demonstrates a commitment to improving the environment.

CO<sub>2</sub> emissions per unit of energy delivered to a site depend on the fuel source, electricity generating mix, and other assumptions. Current values are: Gas 0.21, Oil 0.29, Coal 0.32, Electricity 0.72 kg CO<sub>2</sub>/kWh delivered fuel. The value for on-site combined heat and power (CHP) generation can be much lower.



Graph 3 Building-related energy



Graph 5 Gas consumption

### Notes on Energy Costs

Fuel costs vary with factory size, type, region, contract and load profile. 'Unit prices' tend to be lower for larger sites because of a better negotiating position. For this reason, and to protect the confidentiality of individual sites, the following typical unit prices have been used in all studies in this series.

Typical unit price (p/kWh delivered)

	Fossil	Electricity
Large site	1.0*	5.0
Small site	1.3	8.0

\*Interruptible gas: 0.8 p/kWh

### References

1. Energy Consumption Guide 18. Energy efficiency in industrial buildings and sites, London, EEO, 1993.
  2. Introduction to Energy Efficiency in Factories and Warehouses, London, EEO, 1994.
- Contact BRECSU for other Good Practice Case Studies and Guides on energy efficiency in industrial buildings.

### Acknowledgements

The co-operation of the owners, managers, and occupants of the Case Study building is gratefully acknowledged.

Date installed	Measure	Equivalent 1992 investment costs (£)	Annual energy savings (kWh)	Annual cost savings (£)
1977-81	Re-roof bays 1-4 & 6	92 500	2 250 000	22 500
1978-80	Lighting upgrade of engine works	88 700	300 000	15 000
1989	Replacement of engine works space heating system	CEM FUNDED	7 500 000	SHARED SAVINGS
1989	Installation of BEMS			
1989	Replacement of general office boiler			
1989	Installation of fast-acting door			
1990	Re-roof of bay 10	*16 350	360 000	3 600

\* Additional cost over uninsulated roof

### Summary of measures and savings